

# **AUTOMATED MAPPING OF FRAGMENTS IN MSM TEST AT UTTR**

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## **ABSTRACT**

The tasks associated with the fragment recovery from accidental or intentional detonation of munitions storage facilities constitute the most important elements of post-blast investigation. Depending on the size of the potential explosion site (PES) and the topography exhibited at the exposed site (ES) the fragment recovery range can extend well in excess of 2000 m radius. Furthermore, a reasonable survey of the blast-induced hazardous fragments associated with a given event would generally require mapping of the location and bearing of each individual debris with respect to a pre-selected reference point and an established reference line, respectively. Because of the large number of primary and secondary fragments produced in such events, the field recovery procedure and subsequent analysis in the office can be extremely difficult, tedious, and time consuming. Therefore, utilization of an automated mapping technique can improve the accuracy as well as the efficiency of the field operation and save time for the associated analytical works in the office. This paper represents an innovative approach for automated mapping developed under the DOD SBIR Phase II contract for the United States Air Force by Bakhtar Associates. The recent Munitions Storage Module (MSM) test, performed by the US Air Force at the Utah Test and Training Range (UTTR), is used to demonstrate the technique and elaborate on its accuracy and cost effectiveness.

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## **INTRODUCTION**

In its simplest form "automated mapping" refers to the generation of a plot or map, by a computer, from digital data collected in the field. Recent advances in surveying hardware have increased efficiency of the data collection in the field as well as the computer added drafting time in the office. In the Air Force Munitions Storage Magazine (MSM) Test, performed at the Utah Test and Training Range (UTTR), a very complex topographic survey problem was presented. Due to the size and scope of the test a massive number of points to be collected was generated. The points would have various descriptions which would need to be represented in the data files as well as the plots. Using the standard surveying methods approximately one point per minute can be collected using typical instruments with computerized data collectors. Generally speaking, one hour of field time requires two hours of office time to generate the plots needed. Based on these conditions the survey of the fragments would have been a tedious and an expensive job.

To increase the speed and efficiency of the data collection tasks in the field, a Nikon DTM750 field station was used. The instrument has a built in data collector and DOS processor to eliminate separate devices and also to eliminate duplicating data entry. The measurement of distances and angles for each point are done simultaneously to accuracies of 2 seconds of arc and 2 mm. + or - 2 ppm (parts per million). In distances of 1000 feet an accuracy of better than .009 feet can be achieved. Initial measurement time or time the instrument takes to shoot a distance is less than 1.5 seconds. Descriptors of points measured (bomb fragments, rebar, concrete, etc.) are in alpha text files and are automatically entered by a single keystroke. These features and some innovative field procedures allowed for a more than 400% increase in points collected. An average of 275 points per hour field collection time was achieved.

## **APPROACH**

The approach adopted in the Bakhtar Associates algorithm for the fragment recovery procedure was initially tested in the US Air Force scaled-model tunnel explosion tests (Bakhtar, 1993). However, the scaled model tests were conducted under 1-g at a geometric and strength scale factors of 20:1 (i.e.  $\{\text{Prototype Property}\}/\{\text{Model Property}\} = 20:1$ ). Therefore, the segments over which the fragment recovery was made was fairly small in comparison to a prototype test such as the MSM explosion event. To expedite the field activities and associated office tasks an improvement on the recover operations was made by employing a Nikon field station and increasing the number of location identifier reflective prisms.

The office time for processing the data collected was cut drastically by using the field data to automatically generate the plot. This is done by two deviations in standard survey methods. The first change is to create 3D coordinates in the field rather than angles and distances. By doing this we eliminated office time in generating coordinates. We also eliminated rotation and transformation errors created by multiple occupied points. In the MSM test at UTTR four different points were occupied for data collection. Orientation of the data was achieved because all occupied points had 3D coordinates relative to each other. Also known azimuths between the four points allowed for easy checks on each set-up prior to data generation. Since

the data format used by the DTM750 is in binary raw forms, coordinates can be generated and saved in several formats. The field data is written to a PCMCIA card and files are simply copied to the office computer.

To generate the plot, field Descriptors are used to automatically generate a plot file. For the MSM Test a customized program for Bakhtar Associates was used. Each point collected in the field had a Descriptors given to it. The computer reads the Descriptors and assigns plotting commands as shown in Table 1. From the data file the computer reads the Descriptors and generates a plot file which can be viewed on screen or paper. Any editing can then be done graphically. During the MSM Test, plots for each days work were generated within an hour after arriving at the office. This was useful for job planning for the next day operations.

Another advantage of automated mapping is that any grid needed can be overlaid graphically for the plot. The entire plot can then be generated using different scales or orientations. The plot file can be either an HP plot file or a DXF file. Refer to Figure 1 for a typical grid. By using these automated mapping techniques, office time was reduced to less than 20% of field time rather than 2 times field time. Accuracy and reliability of data was increased by eliminating multiple manual entry of data. All data from the field was in either ASCII or binary form on the PCMCIA card. Copying files took 2-3 seconds per file. The combination of increased field efficiency and automated data handling allowed for a sizable savings in time and expense. The savings over manual methods can be seen in Table 2.

The savings increases exponentially for larger jobs. At the Air Force Scale Model Tunnel Explosive Test (Bakhtar 1993) a smaller number of points was collected. Still in relationship to the standard survey methods the time difference could be measured in days. The total collection time and processing time was approximately 80% less than expected.

Besides generating plan view plots, contour plots can easily be generated using field created line work for breaklines. Figures 2 and 3 show the plan view and contour maps generated for the MSM test, respectively. Both plots were generated with less than 10 minutes of office time. The plots shown represent the post-blast crater which was created at the location of the "engineered system" hosting the bombs at the MSM Test.

## **CONCLUSION**

In conclusion; recent advances in surveying hardware, and flexibility in field techniques allowed for an increase in efficiency for the MSM Test at UTTR. The savings is exponential relative to the number of points to be collected. The final product from the field can be viewed not only by text but by graphic representation. **PRODUCTIVITY and COST ANALYSIS: Manual versus Automated Approach**, shown in Table 2.

The use of electronic surveying systems has produced impressive increases in productivity when compared with manual field and office surveying methods. These productivity increases have been documented by both survey equipment manufacturers and end users and are examined later in this section.

For comparison purposes, manual surveying methods are defined as being a three person field party using an optical theodolite with top mounted EDM and manual recording of field measurements into a field book. In the office, the data is manually entered into a computer or a handheld calculator for processing. All plotting and drafting is performed manually. Electronic surveying methods, in this case study, involve a five person field party using an electronic total station with on-board data recorder in the field and, in the office, data transfer, data processing/reduction and plotting are all performed electronically.

Overall productivity increases are realized in field-to-office automation. There is, however, a significant difference between field productivity and office productivity increases. On topographic mapping projects, Roth (1990) suggests a three to one increase in field productivity, a ten to one increase in productivity in drafting field gathered data and a twenty to one productivity increase in generation of contour maps.

The manual method data referred to by Stenmark (1990) and the results of the MSM test at UTTR are used as the basis for comparative productivity and cost analyses between manual and automated approaches. An automated approach yielded productivity gains over manual methods of about 3:1 for fieldwork and 40:1 for office work. Cost savings in excess of 50% were realized using an automated approach.

### **ACKNOWLEDGEMENT**

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## **TABLE 1. AUTOMATED MAPPING BY USE OF DESCRIPTORS**

Generally data formats for surveying consist of the following:

- POINT NUMBER
- NORTHING
- EASTING
- ELEVATION
- DESCRIPTOR

The delineation can be column or comma. Also the fields can be changed depending on the format of the engineering software used. A typical DESCRIPTOR such as concrete for the MSM Test gave several commands to the computer for drafting. For our field use the DESCRIPTOR concrete represented a piece of concrete located in the field which met the criteria for a hazardous fragment.

The following are the fields which the DESCRIPTOR concrete automatically set into the plot file:

1. The symbol drawn
2. Whether to draw the symbol to ground units or plot units
3. The size in inches/cm to plot the symbol
4. The pen number or layer to draw the symbol
5. Annotation for the point
6. The position of the annotation relative to the symbol
7. The size of the annotation
8. The pen number for the annotation
9. Whether to connect like Descriptors with a line \*
10. The line type to use
11. The pen or layer to draw line with
12. Whether to use the elevation for contouring

- \* For line generation the usual concept is that the previous same DESCRIPTOR will be connected to a like DESCRIPTOR if required by the plotting commands.

**TABLE 2. PRODUCTIVITY COMPARISON: MANUAL AND  
AUTOMATED APPROACHES**

TOPOGRAPHIC/LOCATION SURVEYS.

Topographic surveys containing 1000 (Manual) and 2,500+ (Automated) locations was performed. A listing of X, Y and Z coordinates and a plot of the point locations with elevations was produced.

	<u>MANUAL</u>	<u>AUTOMATED</u>	<b>PRODUCTIVITY <u>RATIO</u></b>
Number of Points	1000	2500	
Field Time (Manhours)	49.8	45.5	
Points/Manhour	20.1	54.9	2.7:1
Office Time (Manhours)	16.0	1.0	
Points/Manhour	62.5	2500	40.0:1

**TABLE 3. PRODUCTIVITY COMPARISON  
COST COMPARISON: MANUAL AND AUTOMATED APPROACHES**

**Discussion and Assumptions.**

1. Office Time.

Office time includes project research time, processing of field data and drafting.

2. Field to Office Time Ratio.

Informal studies indicate the ratio of time spent in the field to that required in the office is in the range 1:1 to 1:2. This analysis assumes a 1:1 ratio based on the above manual method data.

3. Employee Wage/Salary Costs.

The following hourly wage rates are assumed:

Surveyor	\$ 30.00
Survey Technician	\$ 20.00
Draftsperson	\$ 20.00

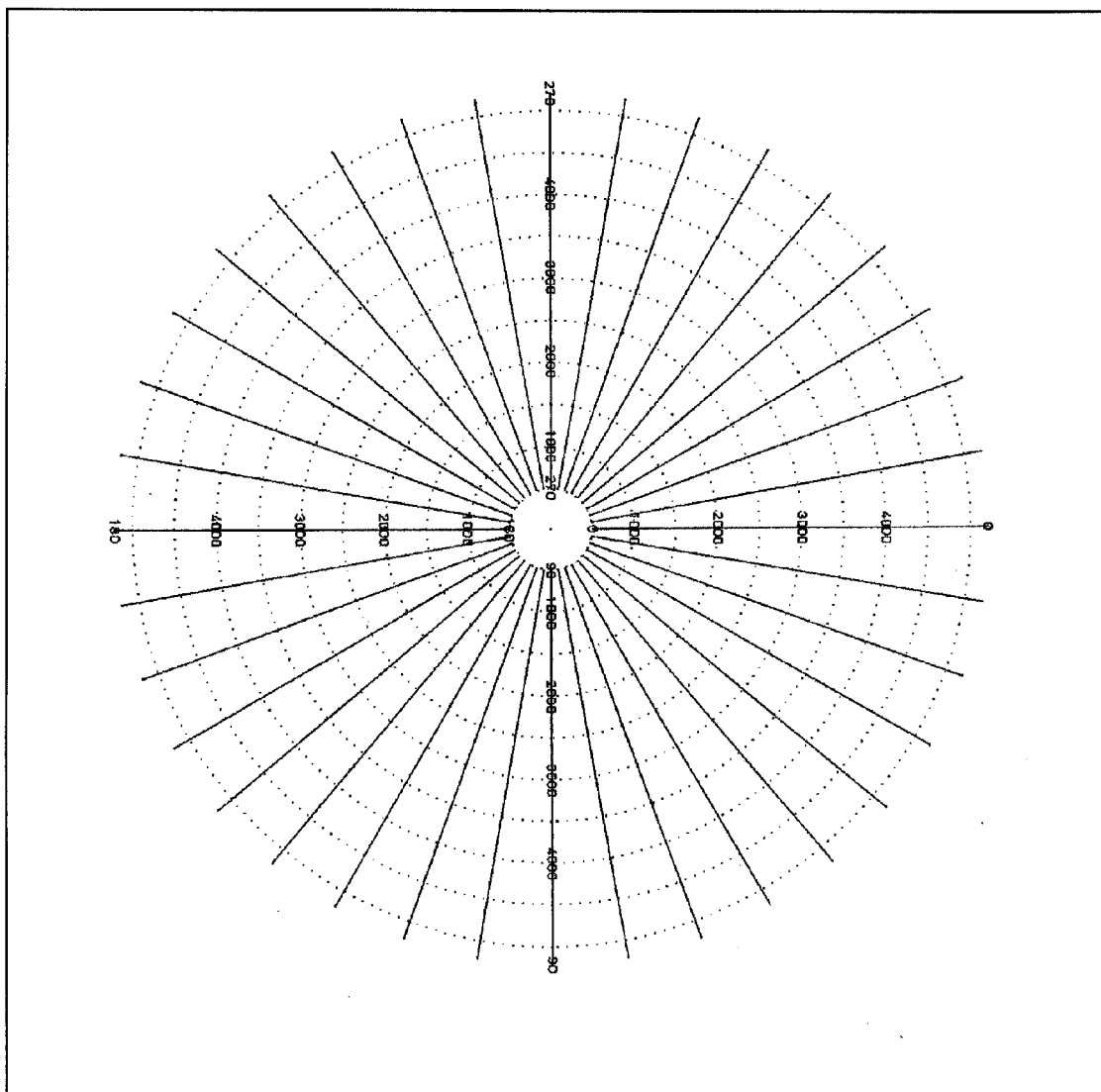
4. Analysis of Monthly Project Applications.

For the purpose of this analysis, it is assumed 160 hours/month is spent in performing topographic/location surveys.

	<u>MANUAL</u>	<u>AUTOMATED</u>	<u>SAVINGS (%ages)</u>
Field Time	160	59.2	63%
Office Time	160	4.0	97%
Field Cost	11,200	6,512	42%
Office Cost	3,200	80	97%
<b>Total per Month</b>	<b>14,400</b>	<b>6,592</b>	<b>54%</b>

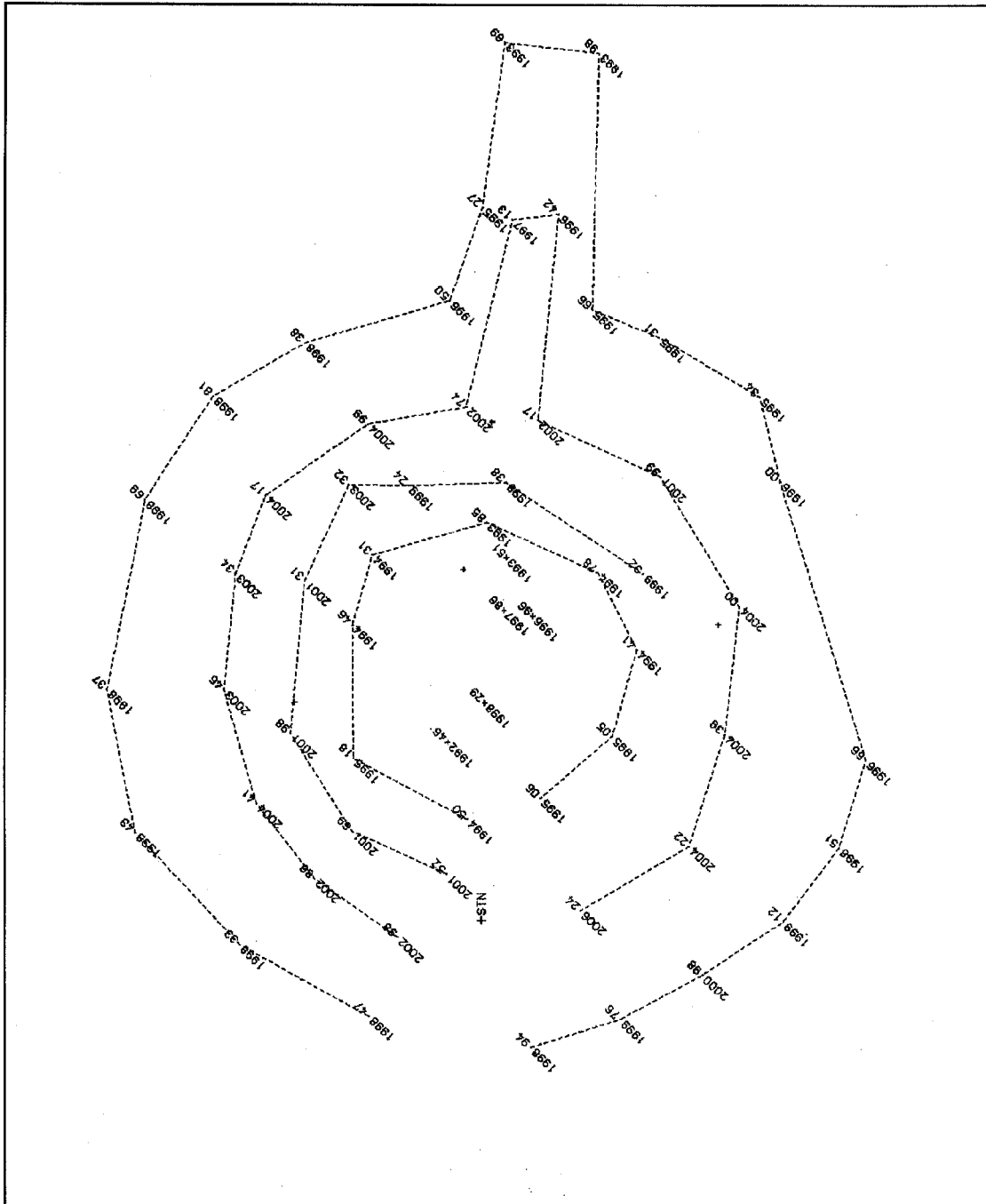


**Figure 1. Representation of a Typical Grid System**

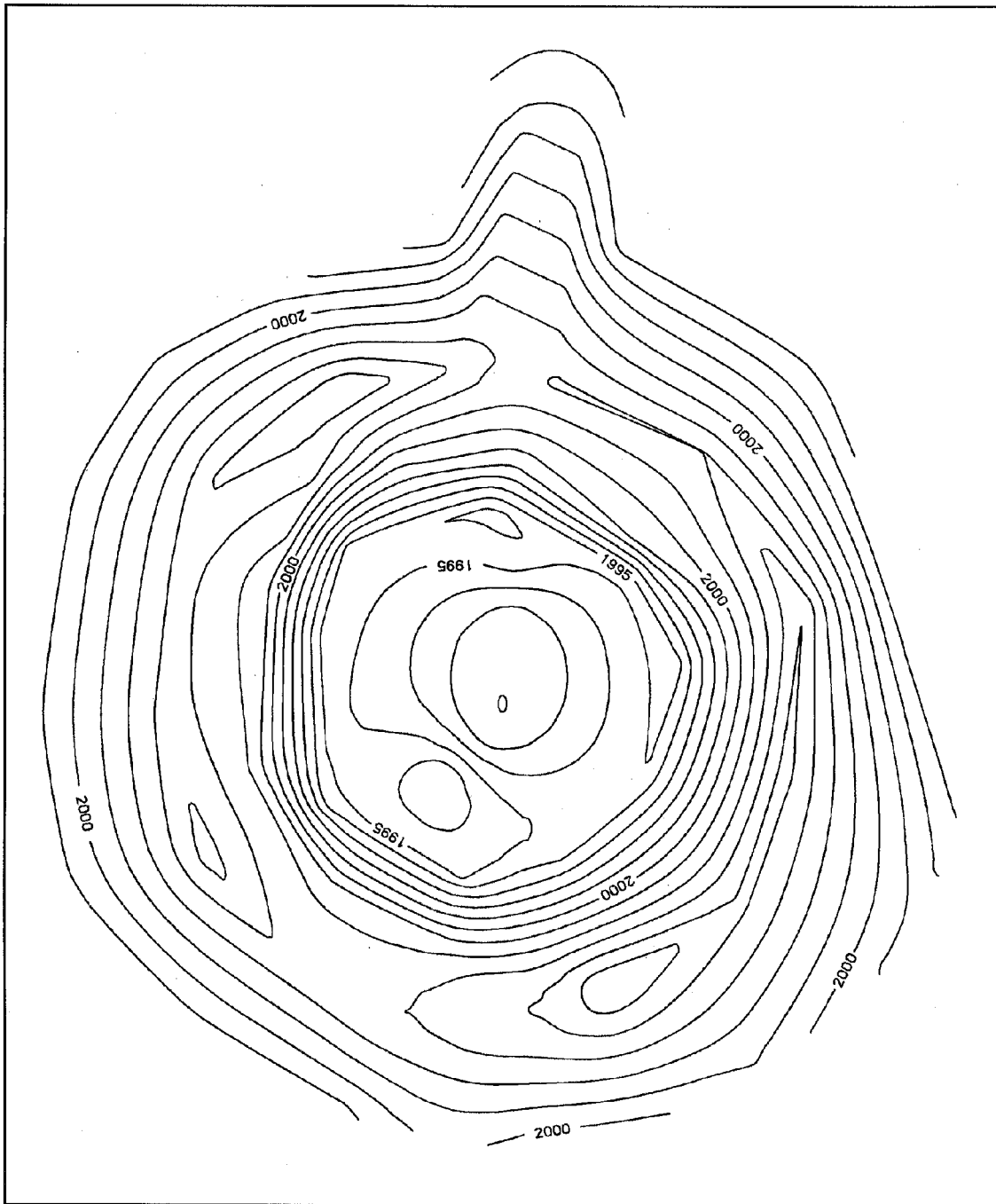


**FIGURE 1. REPRESENTATION OF A TYPICAL GRID SYSTEM**

**Figure 2. Plan View of Blast Induced Crater at MSM Site**



**Figure 3. Contour Map of Blast-Induced Crater at MSM Site**



**FIGURE 3. CONTOUR MAP OF BLAST-INDUCED CRATER AT MSM SITE.**